Wastewater treatment:

Microorganisms, disease and water – from a horror story to a perfect solution

Sis: what happens to all that smelly stuff we flush down the lav?

Photo by Marcin Jozwiak from Pexels

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Before Wastewater treatment

Living in filth. In ancient times, people hunted and consumed wildlife, and later on lived very closely together with their farm animals under filthy conditions. Their wastes piled up in their homes and yards and then in the streets and waterways. They consumed food and water that was inevitably contaminated. Diseases could spread dramatically because personal, private home, public and urban hygiene was nonexistent until about one century ago. Antiseptics and disinfectants were not known at all.

Bad air as an indicator of an unhealthy environment. From the late 13th century onwards, many archives of local authorities and governments in towns in Italy, Spain, England and in the Low Countries (now Belgium and the Netherlands) testify that most European medieval towns were filthy places, teeming with diseases (Black Death or plague, leprosy, etc.) and producing a stink of "bad air".

The hygienic conditions in cities such as Ghent (at that time an important European city with >60,000 people) and Ypres (both now in Belgium), and also Leiden and Deventer (now in The Netherlands), are particularly well documented. In these cities, the hygienic situation deteriorated to the point where the local authorities decided to take measures to protect the health of their citizens. Their policies were based on the prevailing "bad air" or "miasma theory" of Galen. The miasma theory (from the ancient Greek term for "pollution") held that infectious diseases were caused by "poisonous particles/seeds present in polluted air or in food" or in vapor emanating from rotting organic matter, known as putrefaction, or by poor hygienic conditions.

Early steps. City authorities gradually took measures to prevent "bad air" development, including removal of street dirt, garbage collection, improved roads, use of (river) water to rinse the streets, layout of simple gutters and primitive drainage and sewer systems, latrines and cesspits. Also stray dogs and - then common - pigs roaming around in the streets, immoral behavior, gambling, and alcohol abuse were seen as causes of diseases. Exercising mental health and practicing Christian beliefs were believed to contribute to good physical health and wellbeing.

In the 14th -15th centuries, market inspection of meat, fish and grain quality was also introduced. In addition, frauds in trade transactions were scrutinized. All these non-medical actions resulted in a reduction and partial prevention of health risks, and most were actually not *ad hoc* reactions to epidemics!

Hand washing. Hand washing as a hygiene measure was until then not performed, as water was supposed to penetrate the skin and cause an increase in diseases. During plague epidemics in the 15th and 16th centuries and up into the 18th century, the use of water and bathing was forbidden or discouraged, since it was believed that water opened the skin and body for "bad air" to enter. Rich people changed clothes rather than wash, and used perfumes to improve body odour, with hands and faces only occasionally being wiped off.

Of course, the view of water as an imminent danger was not shared by all cultures: the ancient Egyptians, Japanese, Greeks, Romans and others placed a high value on bathing and washed bodies, e.g. as shown by the still existing impressive Roman aqueducts. But in Europe in the Early Modern Era, the fear of water would change only gradually in the 17th-18th centuries, when water finally became perceived as being beneficial to the skin. This led eventually to the installment of primitive collective water supply systems, such as water pumps, canals and aqueducts in the main cities.

Microbes displace Miasma. Only in the period 1860 to 1880, was it demonstrated by Louis Pasteur (1822-1895) and Robert Koch (1843-1910) that small organisms not visible to the

naked eye were the cause of infectious disease. It is startling to reflect on the fact that one had steam engines and train lines between cities by 1850, but a total lack of awareness of the 'power of those super small creatures'.

The search for disinfectants. Then in Glasgow, the surgeon Lister decided to use Pasteur's findings to treat wounds and experimented in 1865 with a range of products that were then in use, such as wine, diluted vinegar, quinine, turpentine and diluted nitric acid, to investigate their ability to kill microorganisms. However, success was variable since none were able to counteract pus formation and inflammation, mainly due to their application after inflammation when decomposition of tissue had already started. They were clearly not useful for *therapy* of infections. But then he turned his attention to *prevention* of infections. He looked for new compounds, such as sodium permanganate and carbolic acid (phenol), and tested them preventively and directly on the human skin or tissue.

Lister had also remembered that at a sewage treatment plant in Carlisle, carbolic acid was in use to lower the stench of the air of rotting garbage and that of the fields that were irrigated with sewage water. This suggestion was made to the sewage plant engineers by Professor Frederick Crace Calvert (1819-1873), chemist at the Royal Institute of Manchester. It was found that carbolic acid also killed the protozoal parasites of the cattle that grazed on the fields and pastures. As a result of Joseph Lister's (1827-1912) work, use of sanitizers such as antiseptics and disinfectants, finally became common practice in the late 1870s.

Koch's Postulates and the identification of disease-causing microbes. Also German physician and microbiologist Robert Koch (1843-1910) significantly buttressed the link between pathogenic microbes and infectious disease with his "postulates", providing in 1876 a logical proof of the germ theory of disease and in identifying the causative bacterial agents of anthrax, namely *Bacillus anthracis* (in 1877), tuberculosis (in 1882), and cholera (in 1884). But we should not forget to mention that he was heavily opposed by a Bavarian chemist and hygienist, Max Joseph von Pettenkofer (1818-1901), Director of The Institute of Hygiene in Munich, Germany. Although correctly being a proponent of good hygiene, clean water provision in cities, fresh air and proper sewage disposal, Pettenkofer did not believe the novel concept that bacteria were a main cause of diseases and stench and came into personal conflict with the famous Koch.

Enter Wastewater Treatment

19th. century: still living in filth and with stench. And that brings us to sewage treatment. We are at the start of the 19th. century yet mankind is still living amidst its filth as in all those centuries before. As indicated above, fecal matter and other organic wastes were commonly thrown in the streets by all citizens. In the city of Ghent, it was the privilege of an order of monks to rear pigs in the city on the filth the pigs could find by roaming around the streets. Clearly, there was plenty of filth lingering all around.

Moreover, feces and garbage are not 'inactive' like sand, but are rich in nutritious components. They thus contain a variety of rapidly growing microorganisms, particularly in the summer. During their growth in wet wastes where there is a deficit of dissolved oxygen, these small creatures make various compounds which are stinky and offensive. Typical compounds are ammonia, amines (cadaverine), sulfur compounds (hydrogen sulfide as produced in rotten eggs).

Moreover, these microorganisms multiply very rapidly (a matter of hours!; compare with even the fastest reproducing mammal) and reach after hours and days of growth numbers of the order of millions per single drop. And most of all, several of them become 'so vigorous and

excited' that they are ready to attack and use for their own purpose of growth, anything they can get. Hence a few drops of contact with the filthy water and the wastes present in the environment was equal to a direct challenge of the citizen by a load of millions of highly 'infectious' microorganisms capable to threaten the life once they get growing in the human body.

The activated sludge discovery. In this context, it is more than surprising that mankind took effective action to remove and treat city sewage only around early 1900. Firstly, attempts were made to quench the foul odor of the collected used waters by blowing air through them. The treated water was subsequently discharged into a local river. However, in 1914, Ardern and Lockett observed in Manchester, UK, that, when they had aerated the sewage, it settled and separated into a clear top layer (effluent) and a bottom sludge layer. When they discharged only the upper water layer and used the sludge to treat the next batch of water, this worked even faster and better in removing the stench and clarifying of the upper water layer. And thus the term was born: "activated sludge".

To the utmost surprise of everybody, this settling material was not inert silt or sand, but alive and kicking with … microorganisms. However, these were good and beneficial types of microorganisms that had been discovered. Ever since, this procedure of providing the correct supply of oxygen to the wastewater, and thus creating conditions for the rapid and massive growth of microbes that use the organic materials in sewage as food, is now practiced all over the world.

Wastewater treatment effectively removes pathogens and massively reduces infections. And not only are organic materials from faeces and other wastes broken down to minerals, the highly competitive environment of activated sludge also eliminates pathogens which are outcompeted and brought to starvation and extinction. Thus, wastewater treatment removes most of the massive quantities of pathogenic microbes released in sewage which were previously the main source of infection in humans. In fact, the water leaving a properly working treatment plant can be reclaimed to irrigate crops and even, as is done now already for more than 2 decades at Oostduinkerke (Belgium), to directly produce drinking water.

In preventing billions of infections, wastewater treatment has become a pivotal component of public health-hygiene measures. Isn't it more than ironic that all those horrendous stories in history of disease due to bad microorganisms are now fully behind us due to good insight and optimal use through bio-engineering of good microorganisms?!! And what a major step forward in health and urbanization has been achieved by humble sewage engineers! *To put this in perspective: before sewage collection and treatment was implemented, the average life span of the European citizen was apparently about 30 years; after good sanitation became implemented, that single factor doubled the life span!!!* Since that major leap forward through sanitation, the development of vaccines, antibiotics and modern health care have further extended life span to almost 80 years. Wastewater treatment is thus our most effective and valuable hygiene and public health procedure that has saved millions of lives and billions of debilitating sickness episodes.

The development of wastewater treatment
was a humanity-changing microbe-based advance!

The Evidence Base, Further Reading and Teaching Aids

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